



Joseph King
Program Director
ARPA-E, Department of Energy

CEMENT = Chemically Engineered Materials Enabled by Novel Technologies

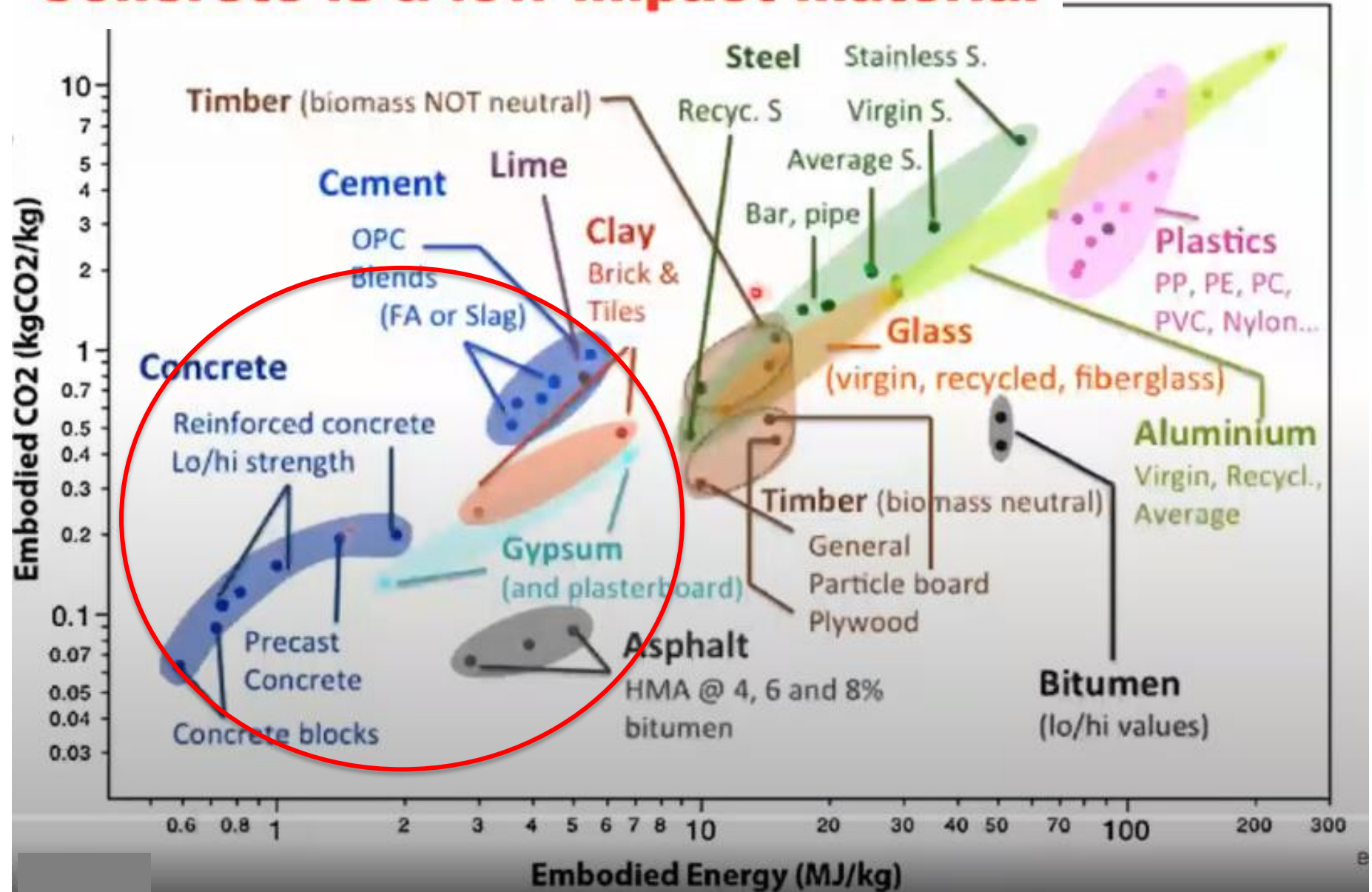
“If concrete were a country, it would rank third in emissions behind China and the United States.”

~30 Billion metric tons of concrete are produced annually*

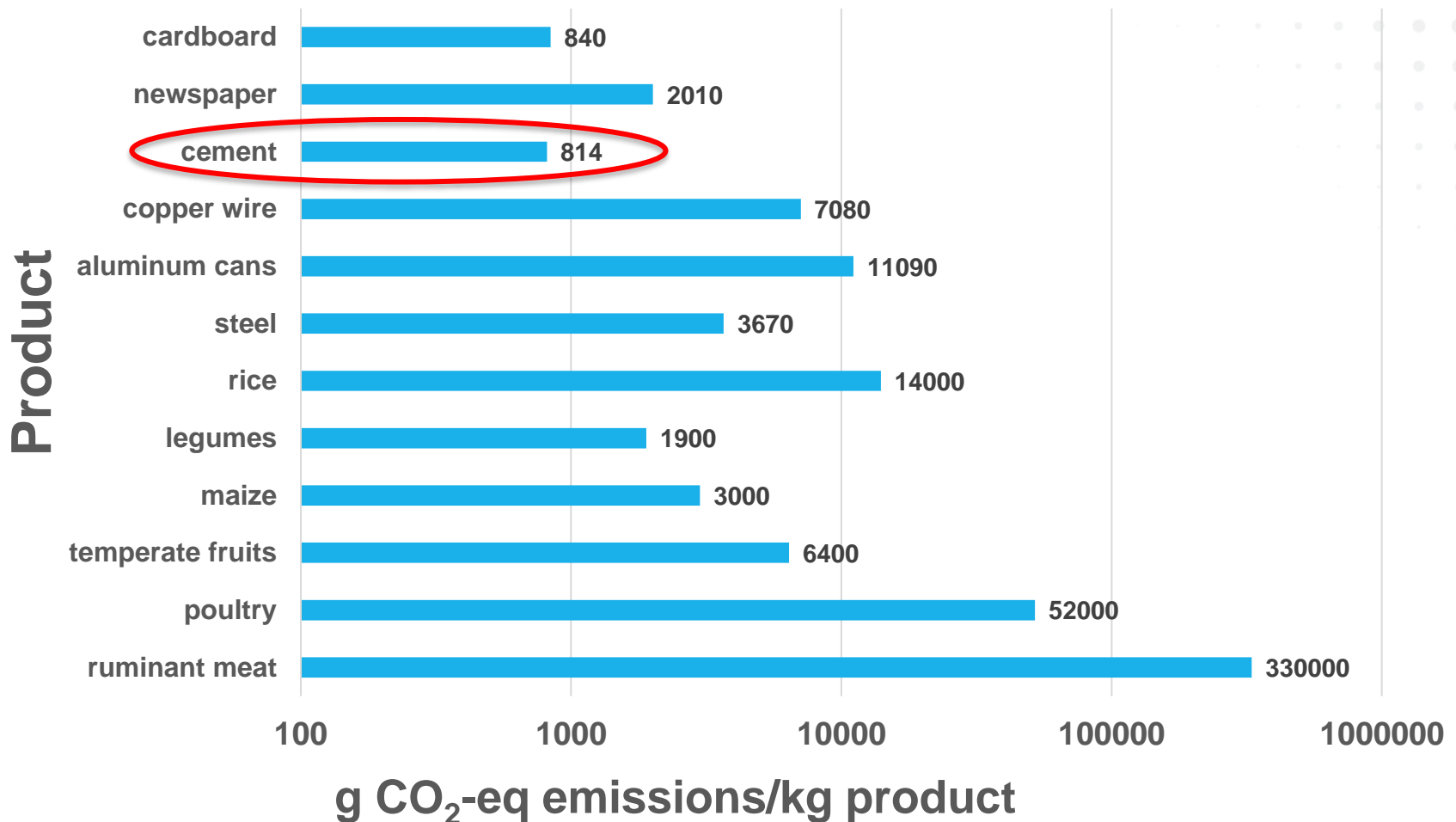
“We aren’t just using more concrete than ever, we’re using more concrete per capita than ever. The global per capita consumption has nearly tripled in the past 40 years”.

*Kimberly E. Kurtis, civil engineer and concrete expert,
Georgia Institute of Technology*

Concrete is a low-impact material

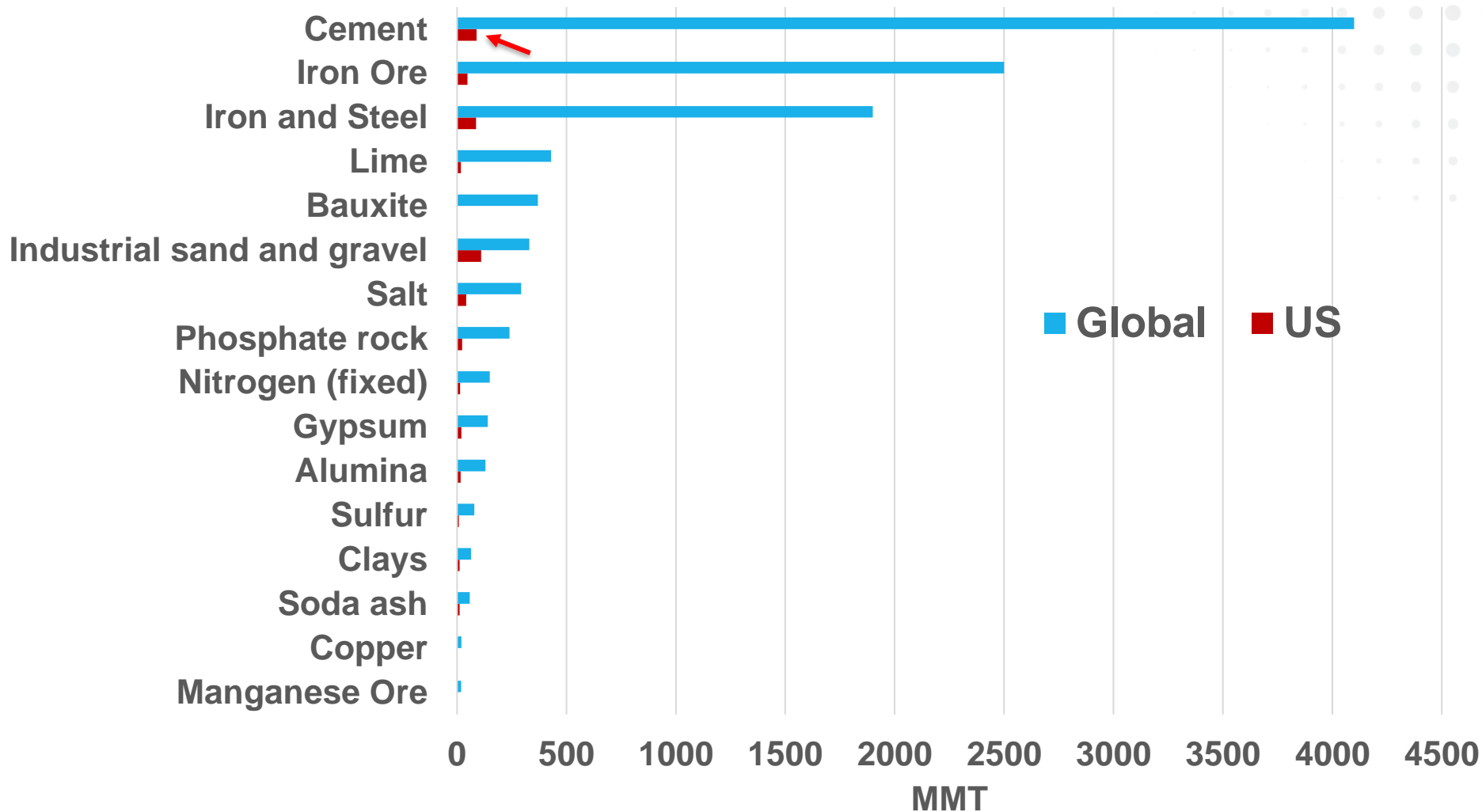


CO₂-eq Emissions for Various Products



The cement industry is one of the lowest CO₂-equivalent emitters on a mass basis.

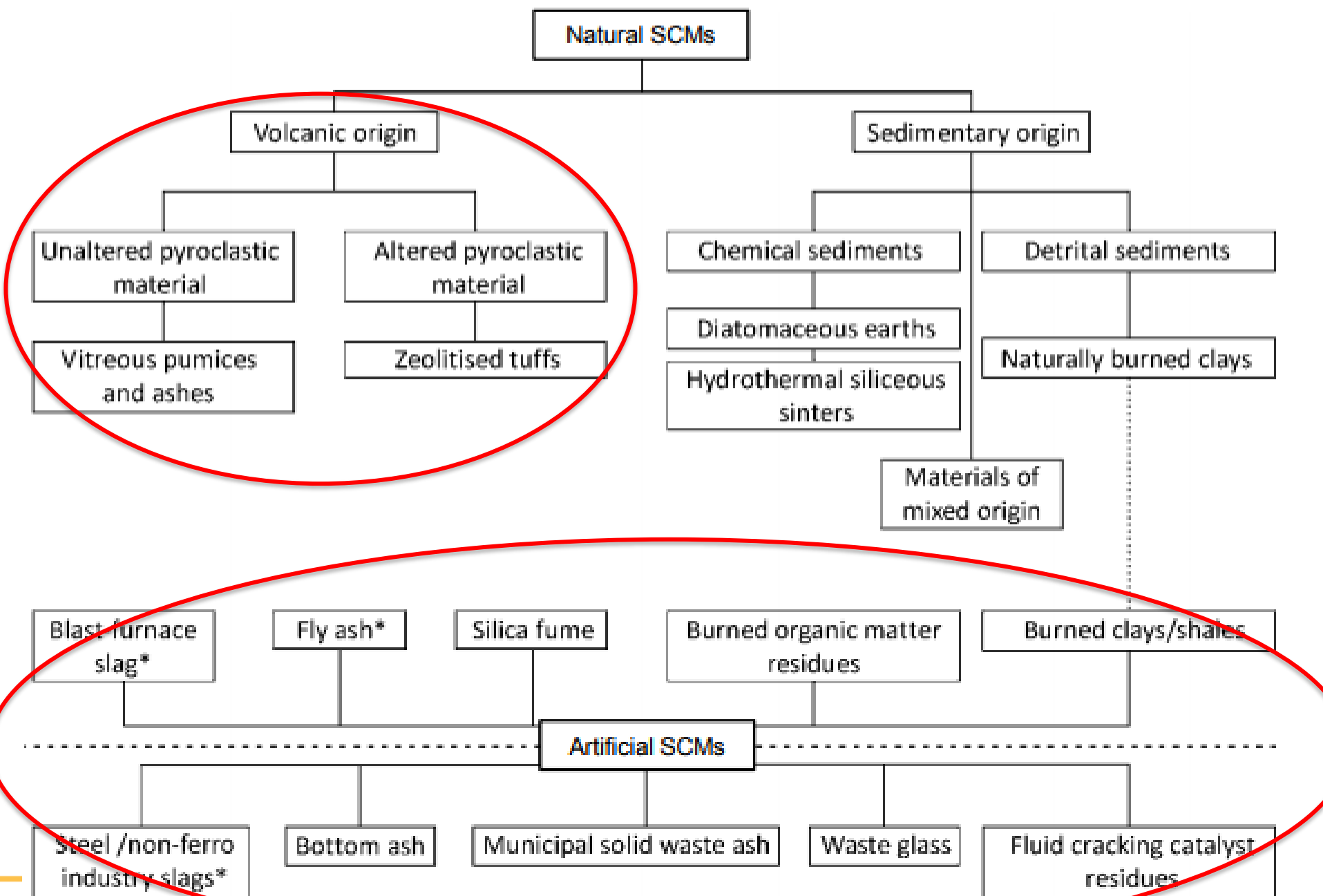
Global Materials Production (2019 Data)



Extremely Durable Concretes and Cementitious Materials: Program Objective

The objective ... is to develop material and process improvements that would:

- (1) Significantly improve the durability** of concrete and cementitious materials, *while*
- (2) maintaining or lowering the energy and emissions** related to production and deployment of the material, *and*
- (3) remaining cost competitive with traditional materials** when accounting for the intended service life and maintenance cycle.

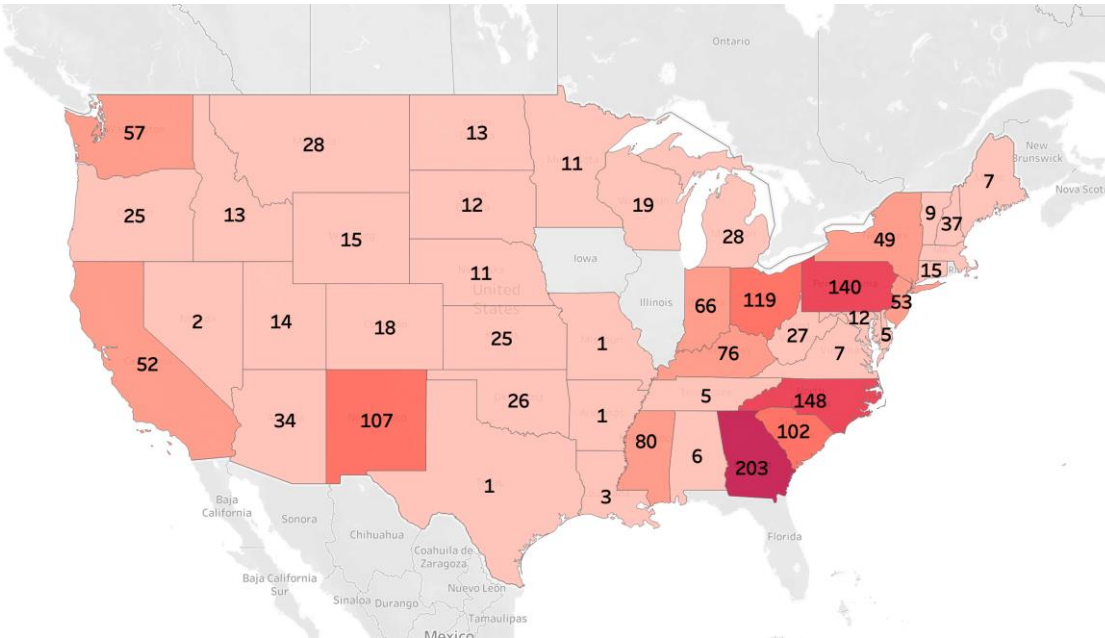


***SCM = supplementary cementitious material**



Infrastructure Status

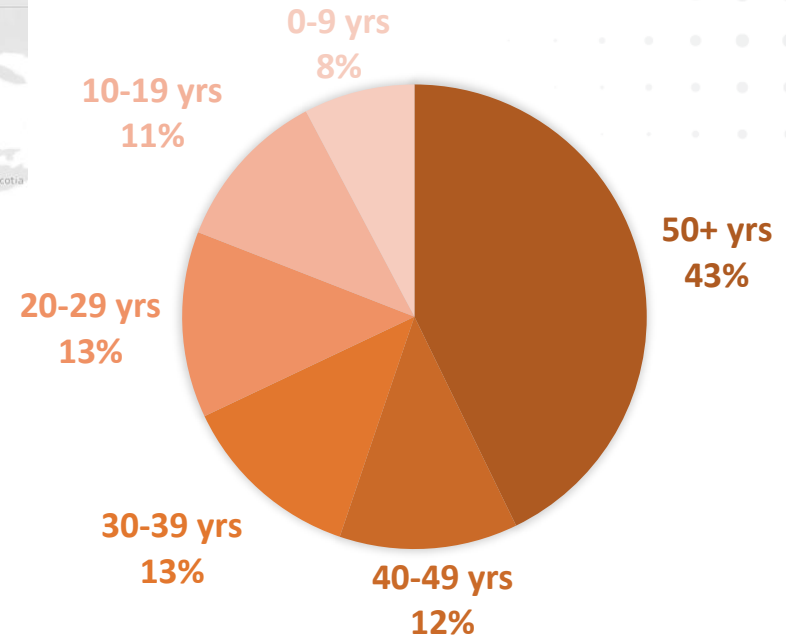
DAMS WITH HIGH HAZARD AND POOR OR UNSATISFACTORY CONDITION



National Inventory of Dams: 1,696.

US Army Corps of Engineers, 2020, National Inventory of Dams. Accessed 10/4/2021. <https://damsdev.net/#/>

DOMESTIC BRIDGES BY AGE

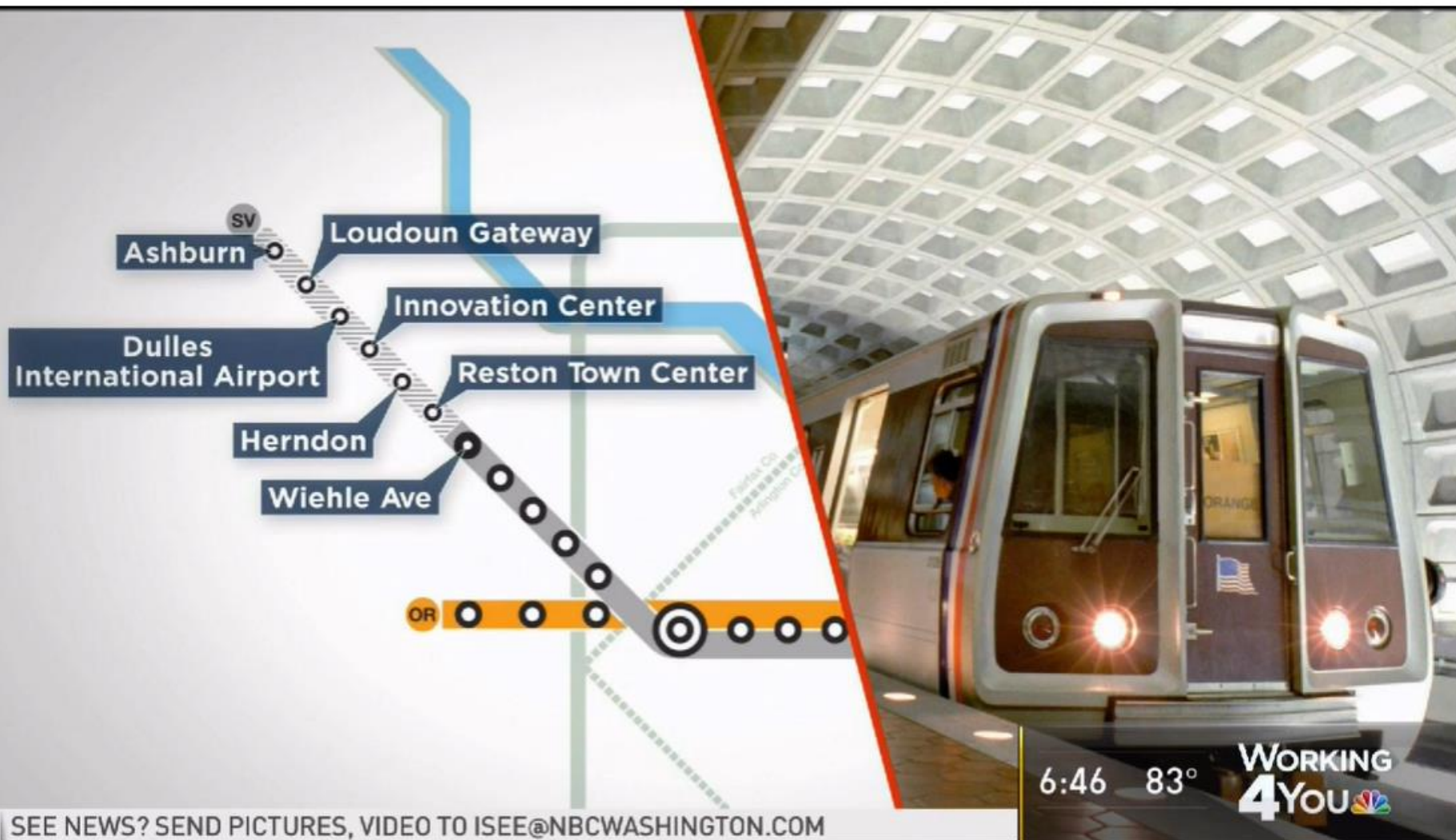


The theoretical design life of a bridge has been 50 years; as of 2020, >43% of existing bridges had exceeded their 50-year useful design life.

Federal Highway Administration, 2020, National Bridge Inventory. Accessed 10/4/2021. <https://infobridge.fhwa.dot.gov/Home>

Concrete Firm to Settle Metro Lawsuit Over Faulty Product Used on Silver Line

Universal Concrete Products is completing its contract



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Transportation Reporter Adam Tuss explains how Metro will have to monitor the Silver Line because of faulty concrete used in construction.

Major Concrete Issues Found in \$2.7+ Billion Silver Line Metro Extension

Project leaders are scrambling **to fix nearly 2,000 areas of concern before the first train rolls**

The construction of the Silver Line has been hampered by material issues, specifically in the area of concrete products. Some of the issues, like **the concrete panels, were caused by fraudulent activities and guilty parties have been identified and penalized.**

Defective Concrete Ties Mar \$2.8B DC Metro Silver Line Project

December 19, 2018

However, other issues were due to inadequate or poor quality control. **For the concrete ties, there may be a tolerance build up issue that should have been identified in the design phase, rather than found in testing after the equipment was installed in the field.**



“It’s not rocket science; it’s rock science.”

Davidé Zampini, Cemex’s head of R&D



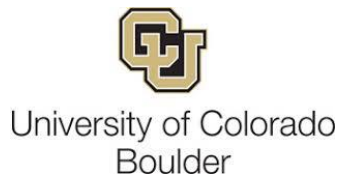
Alternative Binder/Reinforcement Compositions



Processing/Modeling Tools: Thermodynamics, Mechanisms and Kinetics



Novel Protective Coatings



Improved Ductility, Crack Mitigation and Monitoring



2021 ARPA-E CEMENT Virtual Annual Meeting: Day One

DAY 1	OCTOBER 13, 2021
12:00 – 12:05 PM	Welcome Message, ARPA-E Leadership <i>Jennifer Gerbi, ARPA-E Acting Director & Deputy Director for Technology</i>
12:05 – 12:20 PM	Cement Program Update & Outlook <i>Joseph King, ARPA-E Program Director</i>
12:20 – 12:45 PM	Measuring Durability <i>Ed Garboczi, NIST</i>
12:45 – 1:10 PM	Weaving Quantifiable Metrics into Sustainability Goals <i>Robert Spragg, Federal Highway Administration</i>
1:10 – 2:30 PM	Alternative Binder/ Reinforcement Compositions 1 Rutgers University <i>Rik Riman (1:10 – 1:30)</i> 2 University of Virginia <i>Andres Clarens (1:30 – 1:50)</i> 3 Neuvokas Corporation <i>Erik Kiilunen (1:50 – 2:10)</i> 4 University of Kentucky <i>Bob Jewell (2:10 – 2:30)</i>
2:30 – 2:40 PM	BREAK
2:40 – 3:05 PM	Understanding the excellent chloride resistance of LC3 materials <i>Karen Scrivener, EPFL</i>
3:05 – 4:25 PM	Improve Ductility, Crack Mitigation and Monitoring 5 University of Michigan <i>Victor Li (3:05 – 3:25)</i> 6 UC San Diego <i>Yu Qiao (3:25 – 3:45)</i> 7 Washington State University <i>Somayeh Nassiri (3:45 – 4:05)</i> 8 University of Colorado, Boulder <i>Wil Srubar (4:05 – 4:25)</i>
4:25 – 4:30 PM	Day 1 Closing Remarks <i>Joseph King, ARPA-E Program Director</i>

2021 ARPA-E CEMENT Virtual Annual Meeting: Day Two

DAY 2	OCTOBER 14, 2021
12:00 – 12:05 PM	Day 2 Opening Remarks <i>Joseph King, ARPA-E Program Director</i>
12:05 – 12:30 PM	Cement & Concrete: Reducing CO ₂ <i>Eric Trusiewicz, Fellow at Stanford University</i>
12:30 – 12:55 PM	PCA's Roadmap to Carbon Neutrality <i>Rick Bohan, Portland Cement Association</i>
12:55 – 2:15 PM	Novel Protective Coatings & SEED Project 9 Georgia Tech <i>Laurence Jacobs (12:55 – 1:15)</i> 10 C-Crete Technologies <i>Rouzbeh Shahsavari (1:15 – 1:35)</i> 11 University of Florida <i>Chris Ferraro (1:35 – 1:55)</i> 12 Brimstone Energy <i>Cody Finke (1:55 – 2:15)</i>
2:15 – 2:30 PM	BREAK
2:30 – 2:55 PM	All Silica Fume is the Same, Isn't It...? <i>Jedadiah Burroughs, U.S. Army Engineer Research and Development Center</i>
2:55 – 4:15 PM	Processing/Modeling Tools: Thermodynamics, Mechanisms and Kinetics 13 University of Utah <i>Marie Jackson (2:55 – 3:15)</i> 14 Oregon State University <i>Jason Weiss (3:15 – 3:35)</i> 15 UCLA <i>Gaurav Sant (3:35 – 3:55)</i> 16 Carnegie Mellon University <i>Newell Washburn (3:55 – 4:15)</i>
4:15 – 4:20 PM	Closing Remarks <i>Joseph King, ARPA-E</i>

When Endurance Matters



U.S. DEPARTMENT OF
ENERGY

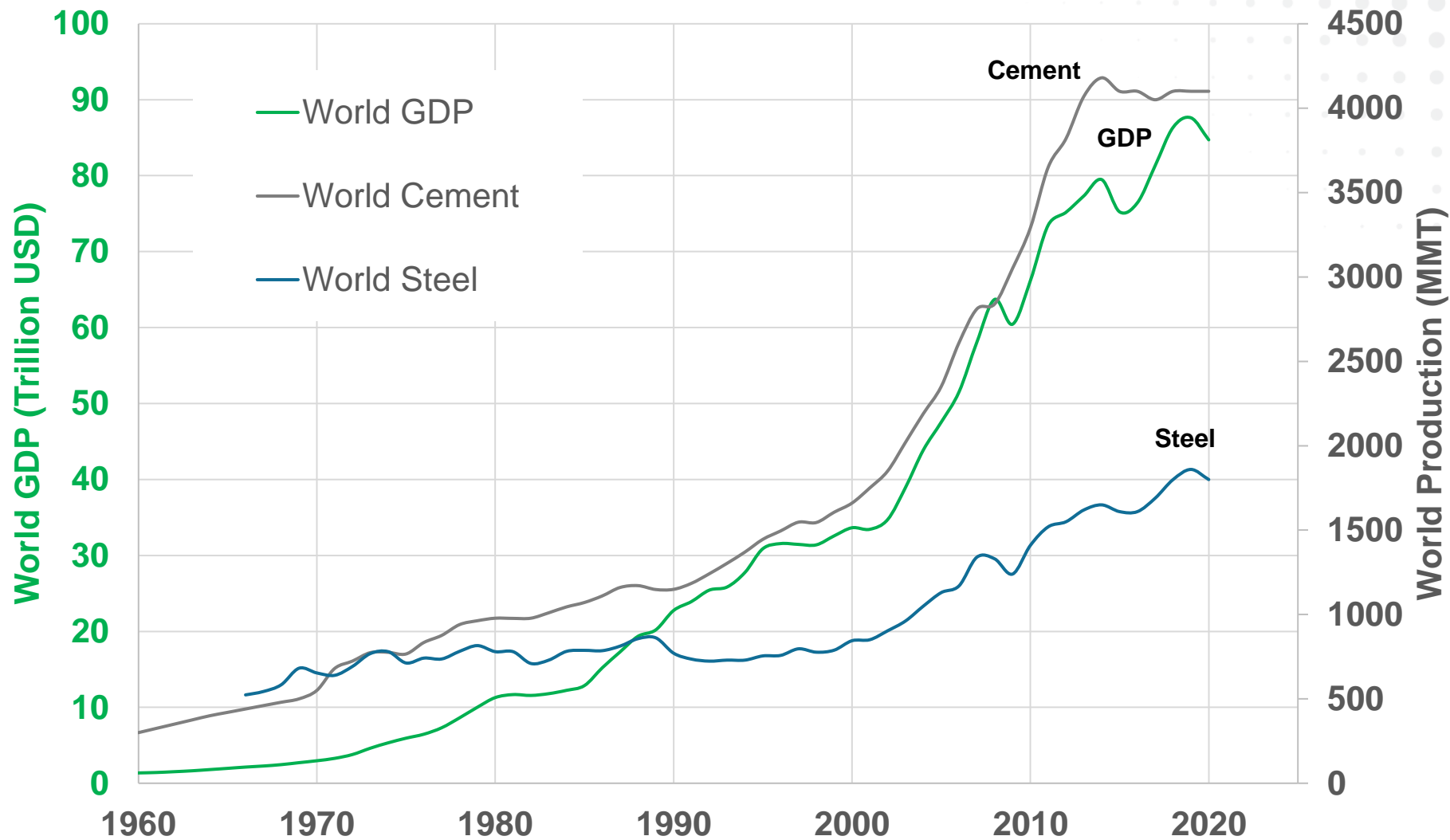
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Alternative Cement Materials Comparison

	OPC	Mg Cements	Wollastonite (Rock/Mineral Wools)	Geopolymers
Compressive Strength (MPa)	35 to >70	50 to 70	~69 ⁸	32 to ≥70
Reserves (MT, Global)	-	8.5 billion ^{2,3,4} MgO precursors	>100 million ²	Extremely Large ^{2,10} "Soil silicates" & Aluminosilicates
Reserves (MT, Domestic)	-	35 million ^{2,3}	"Large" deposits ²	NA ¹¹
Annual Production (MT, Global)	4.1-4.3 billion ¹	27.7 million ^{2,3,5}	>700,000 ^{2,5}	≥37 million ^{2,10}
Annual Production (MT, Domestic)	105-125 million ¹	N/A ⁶	N/A ^{2,6} #3 globally ²	>5.7 million ^{2,10}
Cost (USD/MT)	\$100 to \$110	\$600 ⁷	\$230 to \$490 (domestic) ² \$80 to \$105 (China) ^{2,9}	\$132 ^{2,4}
Limiting Reagents	None	Soluble phosphates	Natural CaSiO ₃ resources	Alkali activators [NaOH ~57 MMT/yr] Chloralkali Process
GHG as Produced ¹²	0.972 MT CO ₂ Per MT cement	(↓) 40%	(↓) 70%	(↓) 80%
Embodied Energy ¹² (production)	0.5 Q primary energy (86 MMT)	-	-	(↓) 30%
Common Preparation/Use	ON-SITE	PRECAST (REPAIR)	PRECAST	PRECAST ON-SITE

Global Cement Production Tracks GDP Growth



If 50 million people say a foolish thing, it is still a foolish thing.

Anatole France

(1844 – 1924, born François-Anatole Thibault, French poet, journalist, and novelist)

One of the painful things about our time is that those who feel certainty are stupid, and those with any imagination and understanding are filled with doubt and indecision.

Bertrand Russell

(1872 – 1970, British philosopher, logician, mathematician, historian and social critic)

“He knows nothing; and he thinks he knows everything. That points clearly to a political career.”

George Bernard Shaw

(1856–1950; Anglo-Irish playwright)